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ABSTRACT

Described is an audio-visual tutorial laboratory program designed to provide a uniform, regularly reinforced, programmatic introduction to a limited set of geologic concepts and features; to provide a sequence of problem-solving exercises on which the student can work as an individual and in which he is required repeatedly to use all elements of the scientific methods in logical and sequential order; and to provide a situation in which a student can work at his own rate, repeat his work as often as necessary, and obtain all the personal attention he may need in the solution of certain problems. Students work in individual carrels, each of which is fitted out with a slide- and sound-movie projector, earphones, a screen, a desk lamp, and miscellaneous equipment for examining rock and mineral samples. Each of the nine units which compose the program is self-contained and has its own content objective. However, all units build on the experiences of previous laboratory work. The report describes the content and activities in each unit and a materials list (with prices) for each unit is given in the appendix. The evaluation of the program, undertaken as a doctoral dissertation project, is described and indicates that the program has been successful, especially in generating student enthusiasm. (PR)

AN AUDIO-VISUAL TUTORIAL LABORATORY PROGRAM FOR INTRODUCTORY GEOLOGY

by

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and

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Grant GY-1436

Final Report

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CONTENTS

FIGURES

TABLE

APPENDIXES

INTRODUCTION...

In 1962, the authors of this report accepted the challenge of developing an introductory course in college geology that would satisfy a number of seemingly contradictory demands. That is, our mission was to design an educationally sound ten-week survey of an exceedingly broad field, which could be taught with a minimum of technical terms and concepts to a large number of university students with little or no previous scientific training. Because this course would also satisfy part of a 15-hour University Basic Education requirement in the physical sciences, it was to provide not only a sound grounding in geology but also an introduction to the scientific point of view for students with widely different backgrounds and career objectives. All this was to be accomplished in a series of about 35 one-hour lectures, in 10 one-hour laboratory sessions, and on a three-hour field excursion.

At the outset, our assignment seemed impossible. However, with the help of a committee that, at one time or another, included nearly everyone on the Geology faculty, we drew up a topical outline and a glossary of terms and concepts. With additional help from staff and students, these grew into a text (Bates and Sweet, 1966), which has served as a generally satisfactory course syllabus since a preliminary version was published in 1964. A variety of laboratory exercises, adapted from previous courses or designed especially for this new one, were used experimentally for the first year or so, then were revised, polished and assembled into a laboratory manual (Sweet, 1963). Finally, a field excursion to a local park was devised to accommodate as many as 1,000 students a term. In short, by 1965, we had a course that met the general objectives of our assignment and we had tested and evaluated it informally with about 7,500 students.

Periodically, in the first several years we offered Geology 100 (Introduction to Geology), we asked students for their comments on various aspects of the course. Their replies were generally positive with respect to the text, the lecture program, the field excursion, and the examinations. However, we collected consistently negative comments on most aspects of the laboratory program from a large number of students. Clearly, if we were to maintain laboratory study as an integral part of Geology 100, it would have to be thoroughly revised.

In organization and content, the laboratory work about which our students complained was not strikingly different from that offered in most college-level introductory geology courses. That is, it consisted of a series of "how to" exercises that involved few problems and demonstrated fewer concepts. Students were instructed in how to identify minerals and rocks, how to read topographic maps, and how to identify fossils. Laboratory instruction was presented by teaching assistants in short, overcrowded sessions, in which it was difficult to assure consistently high-quality presentations and impossible to allow for differences in individual learning modes or rates. Furthermore, time and numbers conspired against the use of experimental or problem-solving approaches to geologic concepts and, in this respect, we generally failed to provide insight into the scientific methods. Finally, our organization of laboratory sessions did not make optimum use of the teaching staff and it imposed a ceiling on total enrollment that was far below demand.

Solutions to all the laboratory problems just mentioned have not been easy to find. However, the program we have devised in the last three years answers many of the problems inherent in its predecessor and it has elicited strongly positive reactions from the students who have participated in it. This program, its objectives, and student reactions to it, are described in some detail in the following pages in the hope that our experience will be useful to those with similar problems in other institutions as well as to those who are interested in audio-visual-tutorial instruction in general.

THE LABORATORY PROGRAM...

Objectives

The major objectives of the laboratory program described herein are to provide a uniform, regularly reinforced, programmatic introduction to a limited set of geologic concepts and features; to provide a sequence of problem-solving exercises on which the student can work as an individual and in which he is required repeatedly to use all elements of the scientific methods in logical and sequential order; and to provide a situation in which a student can work at his own rate, repeat his work as often as necessary, and obtain all the personal attention he may need in the solution of certain problems. In addition to these general objectives, each laboratory unit has its own content objectives. These are listed in discussions of individual program units.

Organization

For conduct of this program at The Ohio State University, we have equipped two rooms (Figure 1) with individual carrels (Figure 2), each of which is fitted out with a slide- and sound-movie projector, earphones, a screen, a desk lamp, a box of miscellaneous equipment (lens, probe, streak plate, glass plate, knife, quartz fragment, etc.), and a "distress flag" that can be raised to signal the assistant that help is needed. Students check into a carrel by depositing their time card in a rack at the laboratory entrance (Figure 3), and they check out a tray of materials from a laboratory aide before settling in to work in a carrel. Carrel use is not scheduled: students can come at any time they wish and stay as long as they like between 8 AM and 10 PM any weekday. Steps in each laboratory unit are carefully specified in a programmed laboratory manual and answers to most program steps are posted in each carrel. However, if a student encounters

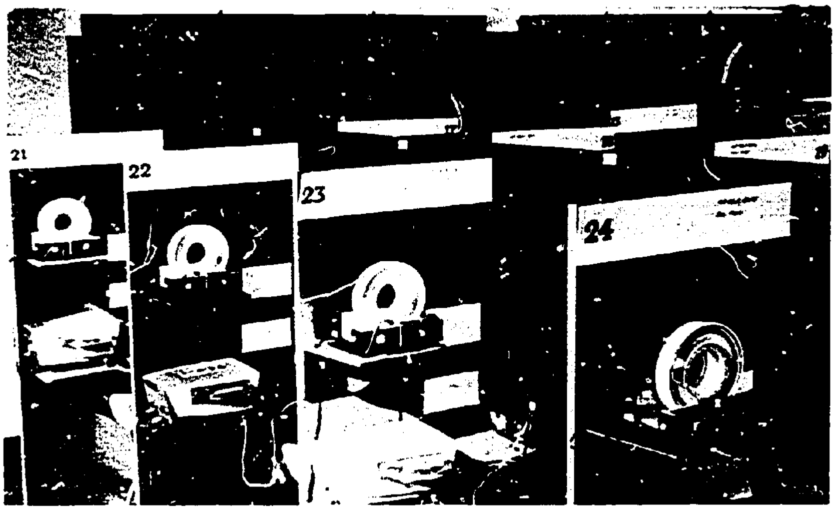

FIGURE 1. The Audio-Visual Tutorial Laboratory at The Ohio State University.

FIGURE 2. A student study station (carrel) in the AVT Laboratory at The Ohio State University.

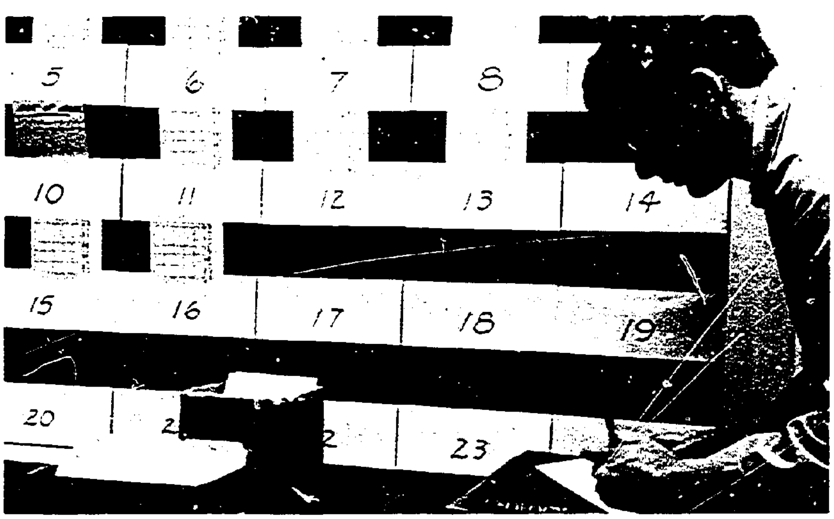

FIGURE 3. Check-in station in the Ohio State University AVT Laboratory.

a problem step (or an answer) he does not understand, he can summon the teaching assistant for help or additional explanation. Special instructions, demonstrations, or experimental situations are on sound films keyed to the unit program: diagrams, thin-sections, landscapes, and the answers to some program questions are on still slides that can be projected for as long (or as frequently) as necessary. Both slides and movie films are loaded by laboratory personnel and students need only turn on the projectors to view these films. When the student has completed the laboratory program, he returns his tray of materials to the laboratory aide (who checks through them before assigning them to another student), removes his carrel card from the rack, signs out, and returns his card to the file. We give no laboratory examinations and we have not required or scheduled attendance. However, each week a few carrels are equipped for review of earlier units, and a week is available at the end of most terms for review of all units.

Laboratory Units

The laboratory program is divided into nine units. Each is self-contained and has its own content objectives, but all units build on the experiences of previous laboratory work. Programs for all nine units are assembled in a laboratory manual (Sweet, Bates, and Maccini, 1969), which also includes pre-lab linear programs for two units and a post-lab program for one. Ultimately, we hope to develop pre- and post-lab sections for all units, but we need more experience with the ones we have written before adding others.

UNIT ONE: The Minerals of Granite and Gabbro.--The theme of this unit is that rocks are composed of minerals and that their differences are a consequence of variations in the amount, arrangement, and kinds of minerals they contain. Mineral constituents isolated from samples of crushed granite and gabbro are described and compared with those of uncrushed specimens of the same rock and with larger representatives of the same minerals. Based on this experience, students write their own definition of a rock and are introduced to cleavage and hardness as two of the physical properties of minerals useful in distinguishing them.

Objectives of Unit One include development of the knowledge that rocks are aggregates of minerals; that minerals can be distinguished from one another through analysis and measurement of their physical properties; and that rocks can be distinguished from one another on the basis of the kinds of minerals they contain. Students also gain familiarity with granite, gabbro, and their mineral constituents; and they gain skill in recognizing and measuring the angles between cleavage planes and in the routine procedures of determining and expressing mineral hardness.

The materials required for Unit One are listed in Appendix A. Film units, developed especially for this unit, include (1) a short introductory segment that emphasizes the variety of crustal rocks and gives the reasons for beginning a study of rocks with granite, gabbro, and basalt; (2) a second segment that identifies cleavage and demonstrates the use of a contact goniometer in measuring the angles between cleavage planes; and (3) a final segment that introduces and explains the use of Mohs' scale of hardness. A still slide showing the correct arrangement of minerals alongside specimens of granite and gabbro is included so that students may check their own arrangements (Sweet, Bates and Maccini, 1969, step 5, p. 5).

<u>UNIT TWO: Igneous Fabric and Texture and The Weathering of Igneous Rocks.</u>--In the first section of this unit, students relate the fabrics and textures of granite, gabbro, basalt, obsidian, felsite, and two porphyritic igneous rocks to physical conditions in the environment of crystallization. In a second section, students are introduced to the concept of weathering and observe the changes that

this process produces in the alaskite granite quarried at Mt. Airy, North Carolina.

Objectives of the first part of Unit Two include reinforced study of rocks and minerals introduced in Unit One; recognition of several additional types of igneous rocks; the use of texture and fabric as an added means of distinguishing between these rocks; and the use of all properties in inferring something about the mode and environment of formation of several common igneous rocks. Our primary objective in the second part of Unit Two is aiding students to develop their own concept of what happens during decomposition of the mineral constituents of granite and helping them apply this concept to other types of rocks and their weathered products.

Materials used in connection with Unit Two are listed in Appendix A. Film units, developed especially for Unit Two, include three short segments. The first, showing basaltic lava flowing down the side of the Hawaiian volcano Kilauea into the sea, relates various cooling rates to igneous rock types with different textures. The second segment, filmed in the laboratories of the Ohio State University Mineralogy Department, demonstrates the conditions under which rocks with granitoid fabric and texture can be produced experimentally. The third segment introduces the concept of weathering and sets the stage for a more detailed examination of fresh and weathered phases of the granite exposed in the Mt. Airy, N. C., quarry.

UNIT THREE: The Formation of Sedimentary Rocks.--A large flow-chart displayed in each carrel lends continuity to this unit, in which students follow the processes of weathering, erosion and deposition to the formation of sedimentary rocks. Study begins with an introductory movie that reviews weathering and emphasizes the separation of weathered materials into two major fractions: a residual regolith and a second component carried away from the site of weathering in aqueous solution.

Erosion, transportation, sorting and rounding of the components of regolith are considered first. A long filmed sequence provides data from laboratory demonstrations on the settling velocities of gravel, sand, silt, and clay-sized fractions of a regolith; and a second, shorter, filmed sequence aids students in relating the degree of roundness of sedimentary particles to differential hardness, length of transport, and abrasion during transport. Once familiar with the processes that modify clastic particles and separate them into textural classes, the student is led to compare unconsolidated and lithified equivalents of these classes; he is provided with the names for the common clastic rocks; and he is introduced to the physical properties of the minerals calcite, limonite and hematite, which are common cements in clastic sedimentary rocks. Recognition of textural classes is demanded by asking students to arrange various clastic sedimentary rocks according to texture in appropriate boxes on the flow-chart and is reinforced by providing a slide that shows the correct arrangement.

Following an introduction to rocks formed from terrigenous clastics, students turn to a consideration of sedimentary rocks formed from materials transported from the site of weathering in aqueous solution. One branch of their flow-chart involves biogenic clastics (coquina, calcirudite, calcarenite and calcilutite); another branch leads to the chemical precipitates (rock gypsum, rock salt, some limestones, and chert). New minerals (gypsum, halite) are introduced as necessary, and rocks are arranged and checked on slides as with terrigenous clastics.

In a second section of Unit Three, students consider three common sedimentary structures (cross-stratification, ripple marks, and mud cracks). A time-lapse movie shows formation of cross-strata in a laboratory tank and emphasizes the uses of cross-stratification in determining current directions and the tops and bottoms of cross-stratified beds. Students are asked to apply observations from the movie to interpretation of a specimen of cross-stratified sandstone, and similar procedures (but lacking filmed instructions) introduce them to the interpretation of ripple-marked and mud-cracked clastic sedimentary rocks.

The principal objectives of Unit Three are (1) to introduce students to an analysis of some everyday materials (residual regolith, hard water) and the textural or chemical components into which they are separated naturally; (2) to introduce them to the common sedimentary rocks that result from lithification of these components; and (3) to provide them with a self-earned basis for understanding a genetic classification or interpretation of sedimentary rocks and structures. The ability to recognize and name the rocks and minerals introduced in this unit is an ancillary objective that is reinforced repeatedly in subsequent laboratory units.

UNIT FOUR: The Use and Significance of Fossils.--A programmed pre-lab section provides background on biologic classification, biologic nomenclature, and the morphologic features of some types of animals found commonly as fossils. In the laboratory, students are first introduced to some of the geologic uses of fossils in a short, largely animated, introductory movie, then asked to make observations on a number of different types of fossils, the distribution of which is keyed to a simple block diagram in their manual. From both morphologic and distributional information, students are led, first, to make inferences about evolutionary mode in several fossil groups (bryozoans, brachiopods, cephalopods), and, second, to use these inferences as a basis for correlating three sedimentary sections. To reinforce the study of sedimentary rocks in Unit Three, students are asked to study and identify several specimens and to enter information about them on the block diagram to which fossil distribution is also keyed. A post-lab section requires synthesis of rock and fossil information gained in lab; relates the distribution of fossils to that of sedimentary rocks; and introduces the concepts of fossil-defined zones as something quite different from rock-defined formations.

Our objectives in Unit Four are numerous. Upon completion of this unit, students should be familiar with the rudiments of biologic classification and nomenclature; they should be able to recognize and use the combination of morphologic and structural features that enables identification of common fossils; they should have some appreciation for the means by which evolutionary statements are deduced from the fossil record; and they should have some practical experience in using fossils in correlating and interpreting stratigraphic sections. Analytic and synthetic abilities are emphasized throughout, from the identification of fossils to the correlation of rocks. "How to" aspects, although necessary to a higher degree than in previous units, follow as rigorously as possible the analysis-synthesis theme of this unit.

Materials used in connection with Unit Four are listed in Appendix A. Most of these materials were collected locally, or were fabricated especially for use with this program. A short introductory movie, with just one segment, explains how and where some types of organisms become fossils and illustrates briefly how fossils can be used to solve certain geologic problems.

UNIT FIVE: Metamorphic Rocks; Rocks and Earth History.--Metamorphic rocks, the last rock class to be studied, are considered in the first part of Unit Five. Changes in texture and fabric induced by metamorphism are illustrated first with a sequence of carbonate rocks, then with the sandstone-quartzite and shale-slate series. The point is then developed that the sequences studied first represent relatively "pure" types, but that metamorphism of "mixed" rocks results in such types as muscovite-marble, mica-schist, talc-schist, garnet-schist, and gneiss.

The second part of Unit Five, a synthesis of preceding studies of rocks of all types, develops the idea that information with respect to the texture, fabric, composition, and spatial distribution of rocks can be combined into a model, from which deductions can be made about major events in earth history. Work in this segment of Unit Five is keyed to a three-dimensional plastic fence-model on which rock bodies and structures are shown in various colors. A largely animated movie explains how information was gained about the spatial distribution of rock bodies shown on the model through direct surface and subsurface observations, geophysical prospecting, and through examination of cuttings and cores from wells. Students then array a set of 11 igneous, sedimentary, and metamorphic rocks on a plastic sheet above places on the model to which they are keyed by numbers and deduce a geologic history from this arrangement. The latter is assembled by arranging in proper relative order a set of 15 cards on which we have printed short descriptions of specific geologic events. The history expressed by this arrangement is discussed with the student by a teaching assistant, who can also suggest different or more reasonable interpretations if necessary.

Objectives of the first part of Unit Five include recognition of the effects of metamorphism on familiar rock types and development of the capacity to deduce from various metamorphic rocks both the original rock type and the conditions that produced the metamorphic rock from it. Our objective in the second part of Unit Five is to relate all the characters of rocks studied up to this point to historical interpretation. In short, we expect students by this stage to begin synthetic and deductive use of all information obtainable from rocks in solving problems that are uniquely geological.

Materials used in connection with Unit Five are listed in Appendix A. One filmed sequence, developed especially for this unit, demonstrates clearly several of the ways geologists obtain information on the spatial distribution of rock bodies and how this information is assembled into a model like the one used in the second part of Unit Five.

UNIT SIX: Maps as Models.--Unit Six begins with a programmed pre-lab section that introduces planimetric and topographic maps, latitude and longitude, map sizes and scales, and topographic contours. Introductory pre-lab material is reinforced through laboratory study that begins with a globe and proceeds to maps of successively smaller areas shown on topographic maps. The use of contours as a means of depicting topographic relief is explained and illustrated in a short filmed sequence that utilizes a relief model and extensive animation.

Our objectives in this unit are admittedly mechanical: the unit is designed to provide the student with some experience and "know how" in the use of maps as models of the earth's surface. Skill in interpreting maps and in recognizing and using map conventions is promoted through a series of short problems involving maps of various types and scales, but these problems illustrate no general concepts and the student "discovers" no important scientific principles. We make no apology for this brief departure from the over-all objectives of our program, for, in many years of teaching, we have found no easy "osmotic" way to interweave map-reading skills with the solution of important geologic problems that require a map as the initial model.

Materials used in connection with Unit Six are listed in Appendix A. The short movie produced especially for this laboratory program features a large relief model on which topographic contours are superimposed through animation while the narrator explains (and the movie shows) what these lines represent. The film concludes with a view of Pikes Peak, Colorado, that fades into a topographic map of the same area.

UNITS SEVEN, EIGHT, AND NINE: The Folded Appalachians and Allegheny Plateau; The Colorado Plateau; A Geologic Excursion Across Colorado.--

In Unit Seven, the student is guided in an examination of the geomorphic and structural features of the Ridge and Valley and Allegheny Plateau Provinces of the Appalachian Mountain System. On a simulated field trip up Lock Mountain, Pennsylvania, the student notes the relationship between beds of different sedimentary rock and topography and this information is later extended to larger areas through use of topographic maps depicting larger regions.

In Unit Eight, the Colorado Plateau Province is examined broadly on maps and slides, then in more detail through a study of the rocks and fossils exposed in the Grand Canyon region. An overview of the entire province is provided by study of a large sectional aeronautical navigation chart. Smaller areas, including the Bright Angel segment of the Grand Canyon region, are studied on 15-minute topographic or topographic-geologic maps. Of particular interest in this unit is the experimental use of a branching program in which students can find information about any one of the several replies they may make to problems posed by rocks and fossils in the Grand Canyon section.

Unit Nine is a vicarious field trip across Colorado, from the Kansas to the Utah borders. Continuity is provided by a highway map of Colorado and a geologic map of that part of the state through which the field excursion passes. Observations at a series of numbered "stops" along the route are made by way of kodachrome slides and, in a number of cases, by specimens collected from rocks exposed at these stops. Students are provided with information from which they can infer geologic structure and interpret geologic history.

Our objectives in Units Seven through Nine are to bring into play, and reinforce in different regional settings, all the skills, abilities, and concepts gained in Units One through Six. An important secondary goal is to introduce students in a "participatory" way to the major features of three North American areas of exceptional geologic interest. That is, rather than tell students all about the geologic features of these areas, we have structured Units Seven through Nine in such a way that students can deduce these features for themselves from a variety of different kinds of observations. By the conclusion of Unit Nine, we hope that students will have gained some confidence in their ability to analyze rocks, fossils, and landscape features and to synthesize their inferences into the sort of historical account of regional development that is uniquely geologic.

Materials used in connection with Units Seven through Nine are listed in Appendix A. Except for rock and fossil specimens and a few of the slides used in Unit Nine, all materials are available commercially. No films were produced for these units, although a long filmed sequence would certainly provide even greater continuity for the field trip of Unit Nine than the maps now do.

A systematic evaluation of the effectiveness of the AVT laboratory program was made during the Autumn and Winter Quarters, 1968-69, by Dr. John A. Maccini, who was then a doctoral candidate in Science Education at The Ohio State University. We include here a brief description of the evaluation program itself and a summary of its results. A more extensive description of the program, and a complete record of the results, is to be found in Maccini's Ph.D. dissertation (Maccini, 1969), which is available to interested persons from University Microfilms, Ann Arbor, Michigan.

Initially, we planned to judge the effectiveness of our new AVT program by comparing the attitudes and achievement of a group of students in the "new program" with those of a group in the "old program." Since both groups would be involved in the same lecture and examination program, and both would be using the same text materials, we assumed that differences in the responses and performances of the two groups would be the result of differences in the two laboratory programs. As the AVT program evolved, however, it soon became apparent that its internal objectives were so different from those of the "old program" that comparison of the two would be essentially meaningless. Hence, we concluded that information of the greatest value to us would have to be derived from an evaluation program that not only measured student achievement and attitudes with respect to the "new program," but also helped us to determine the degree to which we were successful in meeting our own objectives in devising that program.

Procedure

Phase 1.--In Spring and Summer Quarters, 1968, before the AVT laboratory had been tried with students, Maccini constructed lists of formal course objectives and wrote 120 achievement-test items based on these objectives. In the

Autumn Quarter, 1968, these items were administered to samples from the first group of students assigned to the AVT program. Also, at the end of Autumn Quarter, 1968, Maccini asked students in the AVT program to comment, in essay form, on the program in general.

At the end of Phase 1, 100 achievement-test items (some partly reworked) were accepted for use and we had established several things about the laboratory program in general. We discovered that students were favorably disposed toward this mode of instruction; they liked open-scheduling of laboratory visits; and they appreciated the opportunity to work at their own pace. However, it appeared from their comments that they were reluctant to seek help and they were strongly critical of the quality of assistance given in the laboratory. They were particularly insistent that answers be made available immediately to all steps in the laboratory programs, although most of them seemed to recognize that answers were, in fact, woven automatically into subsequent steps. Students commented favorably on the movies and were especially complimentary about the programmed pre-lab for Unit Four.

Phase 2.--In the Winter Quarter, 1969, about 500 students were assigned to the AVT laboratory program. About 260 of these students, all registered in a lecture section taught by Professor Victor J. Mayer, were selected as a test group. Phase 2, then, consisted of a period of data collection, during which information was gathered from university records, carrel-utilization cards, taped interviews, and from responses to the questions on several forms (A through E), of which we have assembled examples in Appendix B.

Some data were collected from the entire test group (carrel-utilization; university grade-point-averages; responses to Forms D and E); some (taped interviews) were collected from volunteer samples from the test group; and others (responses to Forms A, B, and C) were gathered from three different samples of 45 students drawn anew from the test population at the beginning of each week of laboratory work. The latter samples were drawn according to a table of random numbers, but they cannot be regarded as truly random samples because they were drawn without replacement and the population itself changed somewhat by attrition ("dropping") during the term. Each of the procedures used in the evaluation model yielded information on a somewhat different aspect of the total program, so we discuss each part separately in connection with the results produced.

Results

Forms A and B (Unit Achievement Pre- and Post-Tests).--As Form A, quizzes like the one included in Appendix B were administered as unit post-tests; as Form B, these quizzes were given to a different sample from the test group as both unit pre- and post-tests. All items on completed forms A and B were subjected to critical item-analysis and those with high positive discrimination indices and difficulty levels between 0.4 and 0.6 were selected for later use on Form E.

As we had hoped, there were significant differences between the means of pre- and post-test scores for all units except the one given in the last week of the term, when attendance by the test sample was too low to yield significant results. The highest mean pre-test score was on the achievement test given for Unit Four, which was the only unit with a pre-lab program at the time our evaluation program was conducted. The programmed pre-lab must then be considered a successful venture.

From the data gathered from an analysis of responses to Forms A and B, we conclude that our program is successful in that consistent gains in knowledge unique to the laboratory programs are reported in each unit. Further, test items dealing with the programmed pre-lab on fossils, which should then be considered a successful innovation. Finally, since there were moderately high correlations between individual pre- and post-test scores, it seems apparent that most students maintain their same relative standings before and after carrel experience, either as a result of, or in spite of, individual pacing.

Form C (Media Assessment Questionnaire).--On Form C (see Appendix B) 45 students each week were asked to rate from 1 (=high or too difficult) to 5 (=low or too easy) their feelings about the various media (movies, slides, specimens, models, and manual) used in connection with unit laboratory sessions. Ratings, requested in the areas of "liking," "appropriateness," "difficulty," "interest," "informativeness," are summarized in Table I, which shows that mean ratings for nearly all media in essentially all units are above (to well above) the inherently neutral mid-value (3.0) on the five-point scale. Mean "difficulty" ratings on Table I are closer to the neutral (or "just right") mid-value of 3.0 than are means for the same media assessed in different areas, which suggests that although students rated movies, slides, specimens, models, and the manual only "just right" to somewhat more difficult than "just right" in all units, they liked them and found them appropriate, interesting, and informative. In short, students seem to have expressed rather positive opinions about the media we employed in the AVT program, even though they did not regard them as particularly easy -- certainly not "too easy."

Figure 4 compares laboratory absences with unit-by-unit ratings for all media. From Figure 4 it is clear that attendance began to fall off after the fourth week and most sharply after the sixth week, and that, beginning with Unit Four, students became somewhat more critical of (or less strongly compli-

TABLE I. Media Ratings From Form C

MEAN	MOVIES					SLIDES					SPECIMENS					MODELS					MANUAL				
GROUPS	L	A	D	I	N	L	A	D	I	N	L	A	D	I	N	L	A	D	I	N	L	A	D	I	N
(1) 1.0-1.2																									
(2) 1.2-1.4	1																								
(3) 1.4-1.6		3			1							1			1 3					5 7					1 3
(4) 1.6-1.8	3	1		3	3 5	1	9 3 1		9	1 4,9 2	1 2	2 4		1 2	2	1	1 5			3 1	1	1		1	2
(5) 1.8-2.0	2	2 5		1	2	9	4			7 3		3			4 5		7 9		1	4		2		3	5 6 9
(6) 2.0-2.2	6	6		2 6 5	6	4 3	8 2,6 7		1	8	3	9 5 7		3	8 7		3 6 4		5 7	8 9		3		2	8 7 4
(7) 2.2-2.4						6		8	3	6	4		8 4 9	4			8	7		P 6	2 3	9 7	8		
(8) 2.4-2.6	5 4				4	7			7 6 4		9 7	8	3 5	7	9	9 5 6		5,8 3 4	P 6 8		6 7 9	5 P	3,4 9 5,6	5 7	
(9) 2.6-2.8		4	3 5	4		2 8		4 6,3 7	8 2		5		9	5		7 4 3		1 9 P	3 4		P 5 4	8	7 1 2	6 9	
(10) 2.8-3.0			2 1					9 2 1					7 2 1	9		8		6	9			6		4 8	
(11) 3.0-3.2			6 4								8			8							8	4			

L = Liking A = Appropriateness D = Difficulty I = Interest N = Informativeness

Numbers in columns headed L, A, D, I, N are the numbers of laboratory units.

EXAMPLE: Mean rating of movies in Unit 1 was in mean-group 2 in terms of "liking," in mean-group 3 in terms of "appropriateness," in mean-group 10 in terms of "difficulty," in mean-group 5 in terms of "interest," and in mean-group 3 in terms of "informativeness."

Scale on the Media Assessment Questionnaire (Form C) is from 1 (the highest; most difficult) to 5 (the lowest; easiest). The "just right" or "neutral" point in the scale is 3.0.

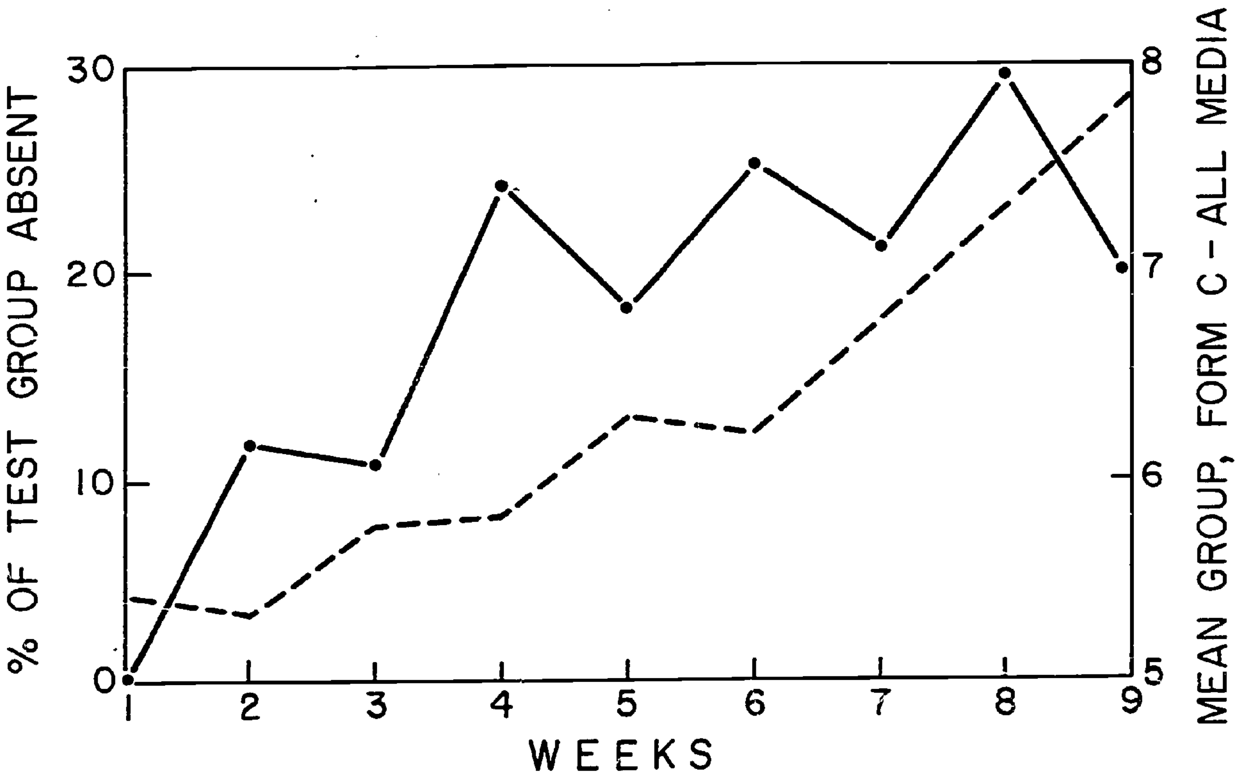

FIGURE 4. Weekly absence record for AVT test group (dashed line) and mean ratings of media shown as mean-classes (see left-hand column of Table I for explanation of mean-classes or groups).

not entirely certain how they are to be interpreted. We should note, however, that Units Four through Nine were deliberately designed to be longer and more challenging than Units One through Three, and that the sharpest increases in the absence curve of Figure 4 correspond in general to times in the term in which mid-term lecture examinations were given in geology and in other courses students were taking. Because the data of Table I tend to support the contention that students "liked" better the media they rated as least "difficult;" because we probably erred in not including questions specifically related to laboratory problems on midquarter examinations; because we "shifted gears" too rapidly between Units Three and Four; and because we have noted over many years of teaching a tendency for there to be a pronounced shift in attitude toward university work in general about mid-way through any quarter, we suspect that a complex combination of factors, including several that have nothing to do with Geology 100, is responsible for the patterns shown in Figure 4. In future evaluation programs, however, we should attempt to manipulate some of these non-lab variables (e.g., exam scheduling and content) in an attempt to isolate the reasons for the patterns of attendance and attitude that seem to be established by the data of Figure 4.

Although it is difficult (and possibly dangerous) to generalize about the data culled from Media Assessment Questionnaires (Form C) for all units, we feel it is reasonable to conclude that students expressed consistently positive reactions to the media we used but, by rating them in different relative orders in different units, students also demonstrated a high capacity to discriminate between media and their impact (or importance) in any particular unit. Movies, for example, are essential to Unit Three and were ranked high; the movie in

Unit Four, however, is introductory and was correctly judged by students to be of less importance than slides, specimens, models, and the manual.

Form D (Attitude Inventory).--Form D (see Appendix B) was given to all 263 students in the test group at the time of their Final Examination. Ninety-five percent of the questionnaires returned were usable and, from these Maccini selected a sample of 45 for analysis.

On Form D, students were asked to check those statements that best expressed their attitudes toward the AVT laboratory program. The 33 statements on the inventory were assigned values from 10.3 (the most positive statement) to 0.6 (the most negative statement). The mean attitude score for the test-sample, whether grouped according to sex or not, was 7.18 with a standard deviation of 1.78; and scores ranged from 2.06 to 8.87, with a median value of 7.91. The statement on the Attitude Inventory (Form D, Appendix B) that most closely corresponds to the median value is "The AVT program has its merits and fulfills its purpose quite well."

From the data gathered on Form D, it is clear that students exhibited a strongly positive attitude toward the AVT program. Nearly 81 percent of the mean scores were at or above the neutral statement (number 17 on Form D, Appendix B), and 68% of the mean scores were bracketed by the neutral statement and the positive statement "Anyone who takes this program is bound to be benefitted." To attach meaning to these results, it is sufficient to note that only 68% of the mean scores were between the neutral and the highest reported positive statement on an evaluation of Columbus high-school students' reactions to the CHEMSTUDY program (Corbett, 1966), and Dr. Marvin Druger, of Syracuse University, reported orally to Dr. Maccini that possibly 25% of his students had indicated negative feelings toward his audio-tutorial program in biology, which is patterned after that of Postelthwait at Purdue University.

Form E (Final Examination).--Form E, intended to serve as a measure of achievement in the entire AVT program, is a block of 30 items selected from Forms A and B. These items were chosen for high positive discrimination indices, and for difficulty levels between 0.4 and 0.6. It was hoped that reliability would be 0.9 or better. Form E was administered with the Final Course Examination to 263 students. For analysis, a sample of 45 was drawn from this population. The mean score for the sample was 16.11 (out of 30); the median was 16.0. Scores ranged from 5 to 28, and a corrected Kuder-Richardson reliability estimate of 0.861 and a mean item-difficulty value of 0.463 indicate that the examination was of high reliability and average difficulty, as hoped.

Correlation between grade-point average and achievement, as measured by Form E, is highly significant at the 0.5 level. Correlation between achievement and average time spent in carrels is negative, which is qualitatively significant, but too small to be statistically significant. There is a positive, but not significant, correlation between attitude (measured by Form D) and achievement (measured by Form E). However, had the sample been larger, there is the possibility that this correlation would have been significant since the value obtained was not much below the level required for significance.

From these data, Maccini concludes (1969, p. 139) that academically more successful students (as measured by their grade-point averages) spent somewhat less time in carrel study, achieved more, and were somewhat more critical of the program than others; whereas less successful students spent more time in carrel study, achieved less, but were more responsive than others to the program because it provided an open schedule, demand assistance, and the opportunity to proceed at a self-regulated pace.

Taped Interviews.--Thirty-five students from the test group accepted Dr. Maccini's invitation to record their comments about the AVT program on tape during the final week of the Winter Quarter, 1969. Analysis of these unstructured comments can be only qualitative, but it supports the conclusion that students favor the program. Most often cited as a virtue was the open schedule that permitted students to work the laboratory into their own schedules. Most also indicated satisfaction with the audio-visual materials, although a number suggested that there should be even more filmed instruction. Also, taped comments support data derived for all units from Form C to the effect that there was widespread satisfaction with earlier laboratory sessions (One through Three) but greater concern about later ones (Four through Nine), which were more difficult. Laboratory Assistants received much praise, as they had on Form C.

Carrel-Utilization Records.--Carrel-utilization cards, providing a record of the number and length of student visits to the laboratory, were examined by Maccini (1969, p. 139-147), who charted attendance of the test group on an hourly basis for each day of the week for all laboratory units. Although these charts are of use primarily in planning future laboratory schedules, they also yielded the information plotted in Figure 4 and discussed in connection with the interpretation of the data derived from Form C. From a study of carrel-utilization records, we have also determined that very few students actually spent two hours a week in the laboratory: Units One and Two required an average of just one hour for completion; Units Three through Seven, and Nine, took an hour and a half, or less; and Unit Eight took an average of nearly two hours to complete. Multiple visits were few in the first two weeks, but increased in the third, sixth, and eighth weeks.

Conclusions from the Evaluation Program

On all counts, and from every point of view, the AVT program described in this report seems to be a successful venture. It is clear that we have designed a program that meets the over-all objectives stated in the introductory section of our chapter on The Laboratory Program, and it is apparently an educationally sound device to which our students have responded with more than ordinary enthusiasm. Their reactions to open-scheduling of laboratory visits and to the type and quality of laboratory assistance are highly positive; they are complimentary in their comments about audio-visual media; and even students with poor academic records have shown enthusiasm and consistently measurable achievement as a result of their laboratory experience.

In response to student comments and performance, we now regularly post answers to laboratory questions in study carrels or elsewhere in the laboratory; we have modified the movies used with the test group to include sound under introductory "leaders"; we have included more enthusiastic, better-enunciated narration on revised versions of our films; and we have written a programmed pre-lab section for Unit Six. Reactions to the branching program of Unit Eight were indifferent to slightly negative, hence we have given up our original intention to use this format more extensively throughout the laboratory manual.

The evaluation model designed by Maccini turns out to be an exceptionally useful one and we recommend its use in studying other programs of the type we have developed. Clearly, we need to find a means to isolate for study the causes of the "slump" in attitude that begins at Ohio State (and perhaps elsewhere) about mid-way through the term; however, this may be a "local" problem and it in no way affects the utility of the evaluation model.

PROJECT SUMMARY...

In an attempt to solve some of the problems that seem to be general in laboratory sections of college-level courses in beginning geology, we have devised, evaluated, and partially revised an audio-visual-tutorial (AVT) program that seems to meet our objectives in a highly successful way. This program, which consists of nine units, is designed to make it possible for students to work at their own pace, at times of greatest convenience to them, but still to receive quality instruction in geology and the procedures of scientific investigation. Development and testing of this program has taken three and a half years and cost a considerable sum of money (Appendix A). However, we enthusiastically recommend the AVT approach to laboratory instruction in geology, particularly in institutions faced with high student enrollment in introductory courses. We plan to use this approach in additional courses in our own curriculum.

ACKNOWLEDGMENTS...

Development of films and the laboratory manual was supported by a generous grant (GY-1436) from the National Science Foundation, to which we are very much indebted. Mr. James Bradford, a graduate student in the Department of Photography, served very capably as producer-director for the films, and revisions of these films were carried out by Mr. Richard B. Long under the supervision of Professor Richard A. Sanderson. Dr. John A. Maccini, who worked with us in development of all the laboratory materials, devised and administered the evaluation program and we are grateful to him for permitting us to make extensive use of his results in this report. Finally, we are especially grateful to the 263 students who so patiently and candidly helped us assess the worth of the AVT program during the Winter Quarter, 1969.

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APPENDIX A

LIST OF EQUIPMENT AND SUPPLIES WITH APPROXIMATE UNIT COSTS

GENERAL

Labmate Geology Carrels (Creative Educational Enterprises, Cleveland, Ohio)	$169.00
Sawyer slide projectors with 3" lenses, remote control	73.00
Sawyer Roto-Tray slide carriers..................................	1.95
Technicolor 1000 sound movie projectors..........................	239.00
Telex headphones with 66" cord, for use with Technicolor projectors..................................	10.00
Projection screen (we use a sheet of white posterboard)..........	0.15
Flexarm desk lamps...	2.00
Specimen and equipment trays (we trimmed down the cartons that contained projectors)..............	NC
Miscellaneous equipment, assembled in wooden boxes, each of which includes: quartz chunk, penny, glass plate, streak plate, steel-blade knife, tripod magnifier, acid bottle, paper towels, millimeter scale, 26" piece of string, wooden foot-long ruler, dissecting needle	3.00
Cost per unit............	$498.10

UNIT ONE

Rock 1-1: 3 x 4" spm. coarse, biotite granite	$ 2.00
Tray 1-1: crushed rock 1-1 (1 3 x 4" spm. supplies 3 sets).......	.65
Rock 1-2: 3 x 4" spm. med.- coarse-gr. gabbro (Minnesota)........	2.00
Tray 1-2: crushed rock 1-2 (1 3 x 4" spm. supplies 3 sets).......	.65
Tray A: 1 x 1" spms. microcline, quartz, biotite, oligoclase, augite	1.61
Contact goniometer	1.35
Slide 1-1: components of granite and gabbro arranged beside the rocks in which they occur	.25
Movie: three segments, with programmed stops between each. First is introductory; second demonstrates cleavage; third demonstrates and discusses hardness.	22.00
Cost per unit..........	30.51

SLIDE 2-1:	Thin-section of granite	$ 0.90
SLIDE 2-2:	Thin-section of gabbro	0.90
ROCK 1-1 :	3 x 4" spm. coarse, biotite granite	2.00
ROCK 1-2 :	3 x 4" spm. medium- coarse-gr. gabbro................	2.00
ROCK 2-1 :	2 to 3" spm. Obsidian.................................	0.50
ROCK 2-2 :	3 x 4" spm. basalt....................................	2.00
ROCK 2-3 :	3 x 4" spm. felsite (aporhyolite)....................	2.00
ROCK 2-4 :	3 x 4" spm. olivine basalt porphyry, dark gray	1.00
ROCK 2-5 :	3 x 4" spm. porphyritic granite	2.00
TRAY B :	1 x 1" spms. quartz, biotite, albite	1.16
ROCK 2-6 :	Fresh, unweathered Mt. Airy Granite (alaskite).......	2.00
CARD C :	Shell vials containing crushed quartz, biotite, and albite in the same proportions as in Rock 2-6; mounted on a 5 x 7" card against a graph-paper background so that relative proportions can be estimated........	0.50
SLIDE 2-3:	Diagrammatic section of Mt. Airy, N.C., granite quarry	0.25
ROCK 2-7 :	Partly decomposed Mt. Airy granite....................	2.00
TRAY 2-8 :	Thoroughly decomposed Mt. Airy granite...............	1.00
SPM. 2-9 :	1 x 1" spm. limonite..................................	0.16
CARD D :	Shell vials containing quartz, weathered biotite, weathered feldspar, limonite-stained clay; mounted on 5 x 7" card against graph-paper background so that proportions of these components of the material in Tray 2-8 can be readily estimated.................	0.50
MOVIE :	Three segments, with programmed stops between each. First shows lava flow spilling into sea and relates texture to cooling rates in igneous rocks; second dmonstrates laboratory formation of granitoid igneous rock; third introduces the concept of weathering through examination of various levels exposed in the Mt. Airy, N. C., granite quarry......................	18.70
		$31.57

UNIT THREE

TRAY 3-1:	Rounded gravel, loose..............................	NC
TRAY 3-2:	Mt. Airy granite regolith; clay with irregular fragments of decomposed granite....................	0.50
TRAY 3-3:	1 x 1" spms. conglomerate, sandstone, shale, siltstone with limonitic cement; 1 x 1" spms. conglomerate, sandstone, siltstone with calcite cement......	1.00
SPM. 3-4:	1 x 1" fragment of hematite........................	0.10
SPM. 3-5:	1 x 1" fragment of calcite.........................	0.50
TRAY 3-6:	1 x 1" spms. coquina, calcirudite, calcarenite, calcilutite..	0.50
SPM. 3-7:	1 x 1" cleavage fragment of selenite...............	0.17
SPM. 3-8:	1 x 1" spm. halite.................................	0.16
TRAY 3-9:	1 x 1" spms. selenite, halite, calcite; tag labeled "SiO2"...	0.85
TRAY 3-10:	1 x 1" spms. rock gypsum, rock salt, limestone, chert..	0.40
SPM. 3-11:	Slab of ripplemarked sandstone, with inked arrow indicating north................................	NC
SPM. 3-12:	Slab of cross-stratified sandstone; "X" inked on one edge, "Y" on the other........................	NC
SPM. 3-13:	Mudcracked Tymochtee dolomite (SC Ohio)...........	NC
SLIDE 3-1:	arrangement of clastic sedimentary rocks on flow chart..	0.25
SLIDE 3-2:	arrangement of limestones on flow chart...........	0.25
SLIDE 3-3:	arrangement of chemical precipitates on flow chart	0.25
SLIDE 3-4:	diagram of symmetrical and asymmetric ripplemarks	0.25
SLIDE 3-5:	view of completed cross-stratification experiment shown in movie..................................	0.25
WALL CARD:	complete flow chart, mounted on heavy card........	0.25
MOVIE :	Four segments, with programmed stops between each. First introduces separation and transports of the fractions of a residual regolith; second provides information on the settling velocities of regolith frations; third demonstrates rounding of particles through abrasion during water transport; fourth is a time-lapse observation on the formation of cross-stratification in a laboratory model........	29.00
		$34.68*

*Many of the sets described in the list for Unit Three were assembled from materials on hand in our laboratory stocks. We have estimated the cost of some of these, but cannot guess at that of others. If all were to be purchased from commercial suppliers, unit costs for this unit would be much higher than the total indicated.

	1 faintly nodose..	$ 0.50
TRAY BR-2:	5 spms. Hallopora: 1 smooth, 3 faintly nodose, 1 distinctly nodose....................................	0.50
TRAY BR-3:	5 spms. Hallopora: 1 faintly nodose, 3 distinctly nodose, 1 with nodes joined into ridges..............	0.50
TRAY BR-4:	5 spms. Hallopora: 1 distinctly nodose, 3 with some nodes joined to form ridges, 1 with all nodes joined to form ridges................................	0.50
TRAY BR-5:	5 spms. Hallopora: 1 with some nodes joined to form ridges, 4 with all nodes joined to form ridges.......	0.50
TRAY BR-6:	1 horn coral, 1 fragment of colonial coral...........	0.75
TRAY BR-7:	1 trilobite (Phacops, Devonian)......................	1.00
TRAY BR-8:	1 straight ammonite (Baculites)......................	1.00
TRAY GR-1:	4 spms. Platystrophia ponderosa (gibbous orthid brachiopod): 1 with 1 plication, 3 with 2 plications in sinus..	1.00
TRAY GR-2:	4 spms. P. ponderosa: 1 with 1 plication, 2 with 2 plications, 1 with 3 plications in sinus.................	1.00
TRAY GR-3:	4 spms. P. ponderosa: 1 with 2 plications, 2 with 3 plications, 1 with 4 plications in sinus.............	1.00
TRAY GR-4:	4 spms. P. ponderosa: 1 with 2, 1 with 3, and 2 with 4 plications in sinus................................	1.00
TRAY GR-5:	1 devonian goniatite with distinct sutures...........	5.00
TRAY GR-6:	1 horn coral; 1 fragment of colonial coral, as in Tray BR-6..	0.50
TRAY GR-7:	1 trilobite (Phacops) as in Tray BR-7................	1.00
TRAY GR-8:	1 coiled ammonite (Scaphites)........................	2.00
TRAY RR-1:	1 Ordovician trilobite...............................	1.00
TRAY RR-2:	4 spms. Platystrophia ponderosa, as in GR-3..........	1.00
TRAY RR-3:	4 spms. P. ponderosa, as in GR-4; 1 orthoconic nautiloid cephalopod showing sutures.................	1.50
TRAY RR-4:	1 trilobite, as in trays BR-7 and GR-7...............	1.00

TRAY RR-5:	1 coiled ammonite (*Scaphites*); 1 straight ammonite (*Baculites*)..	3.00
TRAY GBR :	2 x 2" spms., each with number: 1 = sandstone 2 = green shale 3 = limestone 4 = conglomerate 5 = sandstone 6 = black shale	1.20
SLIDE 4-1:	diagrammatic view of *Platystrophia ponderosa*, with sulcus and plications identified.....................	0.25
SLIDE 4-2:	cephalopods, showing sutures, labeled................	0.25
MOVIE :	One segment, an introductory unit, explaining the nature and various geologic uses of fossils..........	12.50
	Cost per unit............	$39.45*

*The Ohio State University Geology Club collected and sold us for substantially less than retail prices most of the fossil specimens used in this unit. Others we cast in dental plaster in molds made from choice museum specimens. If the specimens listed above were to be obtained from commercial suppliers, costs will be much greater than listed.

UNIT FIVE

ROCK 5-1:	fossiliferous limestone, 3 x 4" spm.	$ 0.25
ROCK 5-2:	polished Holston limestone, 3 x 4" spm.	0.25
ROCK 5-3:	polished marble, 3 x 4" spm.	0.25
ROCK 5-4:	sandstone, 3 x 4" spm.	0.10
ROCK 5-5:	quartzite, 3 x 4" spm.	0.05
ROCK 5-6:	shale, 3 x 4" spm.	0.05
ROCK 5-7:	slate, 3 x 4" spm. showing cleavage..................	0.05
ROCK 5-8:	mica schist, 3 x 4" spm.	0.20
ROCK 5-10:	talc schist, 3 x 4" spm.	0.20
ROCK 5-11:	garnet schist, 3 x 4" spm.	0.20
PLASTIC FENCE MODELS	(See p. 105, Sweet, Bates & Maccini, 1969). Models made to our order by Warner P. Simpson Co., Columbus, Ohio	6.50

TRAY G : 11 1 x 1" spms., each with a number, as follows:

1. schist
2. slate
3. limestone
4. sandstone
5. granite
6. quartzite 1
7. marble
8. Holston limestone
9. quartzite 2
10. shale
11. quartzite 3 .... 1.50

CARD SET: 15 cards, each with a short statement describing a geologic event. Mimeographed on heavy stock............. 0.10

MOVIE : One segment. Explains how geologists obtain information to construct three-dimensional models of segments of the earth's crust. Movie emphasizes surface observations, seismic prospecting, observations of cores and in mines, and magnetic prospecting. Keyed to platic fence model used in laboratory 16.70

Cost per unit......... $26.65

UNIT SIX

PLASTIC GLOBE (Hubbard Scientific Co.) .... $ 5.00

NEW ORLEANS-EAST, LA. 7.5-minute topographic quadrangle............ 0.50

FRANKSTOWN, PA. 7.5-minute topographic quadrangle.................. 0.50

SLIDE 6-1: part of Pikes Peak, Colorado, 7.5-minute topographic quadrangle, used in film 0.25

MOVIE : One segment. A relief model and superimposed lines are used to demonstrate the utility of topographic contours in depicting relief on a topographic map 16.30

Cost per unit.......... $22.55

UNIT SEVEN

FRANKSTOWN, PA. 7.5-minute topographic quadrangle.................. 0.50

PITTSBURGH, PA. 1:250,000 map 0.75

ALTOONA, PA. 7.5-minute topographic quadrangle 0.50

ROCKS 7-1, 7-2, 7-3: 3 x 4" spms. of Reedsville Shale, Juniata Siltstone, Tuscarora Sandstone 0.75

SLIDES 7-1, 7-2: Aerial views of Appalachians and Chestnut Ridge, Pa. (John Shelton) 2.30

Cost per unit......... $4.80

UNIT EIGHT

GRAND CANYON Sectional aeronautical naviation chart	$	0.03
MEXICAN HAT, Utah, 15-minute topographic quadrangle............		0.50
GOULDING, Utah, 15-minute topographic quadrangle...............		0.50
SHIPROCK, N. M., 15-minute topographic quadrangle..............		0.50
SODA CANYON, Colorado, 15-minute topographic quadrangle........		0.50
BRIGHT ANGEL, Ariz., 15-minute topographic quadrangle..........		0.50
BRIGHT ANGEL special geologic map, with sections. Sections cut off and mounted separately as CARDS A and B (available from Grand Canyon Nat. Hist. Assoc.)		1.00
ROCK 8-1: Tapeats sandstone (or reasonable substitute)........		0.25
ROCK 8-2: Bright Angel shale (or reasonable substitute).......		0.25
ROCK 8-3: Muav limestone (or reasonable substitute)...........		0.25
CARDS : A set of 14 cards, each bearing a picture of a trilobite and each the color of the appropriate geologic formation on the Bright Angel special geologic map. (We duplicated drawings by mimeograph on heavy stock of the appropriate colors.)		0.30
SLIDE 8-1: Aerial view of Lake Mead (John Shelton)...........		1.15
SLIDE 8-2: Aerial view of goosenecks of San Juan at Mexican Hat (John Shelton)..................................		1.15
SLIDE 8-3: Monument Valley, Utah (John Shelton)...............		1.15
SLIDE 8-4: Aerial view of south wall of Grand Canyon (John Shelton)..		1.15
Cost per unit..............		$9.18

UNIT NINE

COLORADO State Highway Map, Official 1968 edition (Colorado State Highway Department).......................	$	NC
SLIDE 9-1: Roadside, near Bird City, Kansas..................		0.25
SLIDE 9-2: On Highway 36, near Bird City, Kansas..............		0.25
SLIDE 9-3: Great Plains in Kansas.............................		0.25

SLIDE 9-4: Along highway, near Joes, Colorado....................	0.25
SLIDE 9-5: Last Chance, Colorado..................................	0.25
SLIDE 9-6: Oil rig, on eastern Colorado plains....................	0.25
SLIDE 9-7: Distant view of Colorado Front Range...................	0.25
SLIDE 9-8: Aerial view of Front Range (John Shelton)..............	1.15
SLIDE 9-9: Aerial view of Front Range (John Shelton)..............	1.15
SLIDE 9-10: Red Rocks Amphitheater, Colorado......................	0.25
SLIDE 9-11: View east of Great Plains from near Idaho Springs......	0.25
SLIDE 9-12: Close-up of Idaho Springs Formation...................	0.25
SLIDE 9-13: Idaho Springs formation...............................	0.25
SLIDE 9-14: Overview of Central City, Colorado....................	0.25
SLIDE 9-15: On highway, near Silver Plume, Colorado...............	0.25
SLIDES 9-16, 9-17: Silver Plume granite...........................	0.50
SLIDES 9-18, 9-19: Loveland Pass, Colorado........................	0.50
SLIDE 9-20: Gore Pass, Colorado...................................	0.25
SLIDE 9-21: Lake Creek, Colorado..................................	0.25
SLIDE 9-22: View from top Mt. Elbert, Colorado....................	0.25
SLIDE 9-23: Maroon Peaks, Colorado................................	0.25
SLIDE 9-24: Book Cliffs, eastern Utah.............................	0.25
ROCK 9-1: 3 x 4" spm. red Fountain arkose.........................	0.50
ROCK 9-2: 3 x 4" spm. Dakota Sandstone............................	0.50
ROCK 9-3: 3 x 4" spm. Niobrara Limestone..........................	0.50
ROCK 9-4: 3 x 4" spm. Idaho Springs gneiss........................	0.50
ROCK 9-5: 3 x 4" spm. Silver Plume Granite........................	0.50
Cost per unit.................	$10.30

SUMMARY OF UNIT COSTS

General materials and equipment	$498.10
Unit One materials.........................	30.51
Unit Two materials.........................	31.57
Unit Three materials.......................	34.68
Unit Four materials........................	39.45
Unit Five materials........................	26.65
Unit Six materials.........................	22.55
Unit Seven materials.......................	4.80
Unit Eight materials.......................	9.18
Unit Nine materials........................	10.30
Total cost, per unit........	$707.79

REMARKS

From the summary above, it is clear that it will cost at least $700 to equip and establish one station for the Audio-Visual Tutorial program we have developed. Each station will accommodate 25 to 30 students during a week if it is accessible to students about 50 hours a week. Our basic unit, however, is eight stations (see Figure 1, page 4), and unit costs for carrel construction will considerably increase for basic units of fewer than eight stations.

In a laboratory equipped with 24 stations, we have operated successfully with one graduate Teaching Assistant and one undergraduate Laboratory Aide on duty at all times. These teaching and supervisory personnel cost us about $375 per week, for a quarterly cost (9 weeks) of $3,375.

There are relatively few items of expendable materials or equipment used in our program, but one of these bears mention. Projection lamps for the movie and still projectors have a rated life of about 25 hours and a rather high unit cost. A stock of spares should be maintained, and bulbs will need to be replaced in both projectors about once a term (with use comparable to ours). This adds a continuing operational cost of about $10 per station per term.

Finally, we should note that in many units we have used materials we had in stock or constructed ourselves. Commercial rates for most of these are unknown to us and we have estimated liberally. Also, with assistance from the National Science Foundation, we have produced our own sound-films for this program and the listed cost of these is, for all units, the sum we have had to pay to have duplicates printed and packaged for our own use. Such costs may bear no direct relation to those that may ultimately be charged when distribution rights to our films have been assigned to commercial suppliers.

APPENDIX B

FORMS USED IN PROGRAM

EVALUATION

FORMS A AND B*

Achievement Test - Unit I

1. Which of these is classed as a rock?
   a. Quartz
   b. Gabbro
   c. Augite
   d. None of the above

2. The mineral that is very soft, and is composed of thin, elastic plates that separate easily is called
   a. Quartz
   b. Mica
   c. Feldspar
   d. Granite

3. A rock may most generally be defined as a
   a. substance of very definite chemical composition.
   b. homogeneous mixture of two or more elements.
   c. material with definite cleavage and streak.
   d. mixture of minerals.

4. Mineral Y is scratched by both W and X; however, mineral X is scratched by Z. From these three tests, we can conclude that
   a. W is softer than X.
   b. X is softer than W.
   c. W is as hard as X.
   d. none of the above relationships can be determined.

5. An analysis of minerals present in gabbro would be closest to
   a. 30% quartz, 20% biotite and 50% feldspar.
   b. 5% feldspar and 95% augite.
   c. 40% feldspar, 30% augite and 20% biotite.
   d. 80% feldspar and 20% augite.

6. Two rock specimens from different parts of the world are found to contain quartz, mica and feldspar. To classify them properly, the next step is to determine the
   a. density and specific gravity of each rock.
   b. proportions of each mineral present.
   c. cleavage angles of minerals in each rock.
   d. hardness of each rock specimen.

7. A mineral with three cleavage angles has a minimum of how many cleavage directions?
   a. 2
   b. 3
   c. 4
   d. 6

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*As Form A, this examination was administered as a post-test; as Form B, it was administered as both a pre-test and a post-test.

8. What is the smallest angle (estimated) between the cleavage planes shown in the diagrams? (Diagrams omitted here)
   a. 10 degrees
   b. 75 degrees
   c. 90 degrees
   d. 135 degrees

9. Which of the physical properties listed below is <u>least</u> reliable for the purpose of mineral classification?
   a. hardness
   b. cleavage
   c. fracture
   d. color

10. According to Mohs' Scale of Hardness
    a. absolute values are not assigned to minerals.
    b. diamonds are about nine times harder than talc.
    c. minerals not having cleavage appear as higher values.
    d. the force applied to each mineral must be equal.

FORM C

UNIT ONE - THE MINERALS OF GRANITE AND GABBRO

ITEM I. Movies - "Introduction," "Cleavage," and "Hardness"

1. Dull, tedious; thought of other things	____ ____ ____ ____ ____	Interesting; held my attention
2. Repeated what I already knew	____ ____ ____ ____ ____	Informative; presented new material
3. Too easy to follow; too elementary	____ ____ ____ ____ ____	Too difficult to follow; too advanced
4. I did not like this way of presenting material	____ ____ ____ ____ ____	I liked this way of presenting material
5. Did not fit in well with other lab activities	____ ____ ____ ____ ____	Fit in well with other lab activities

ITEM II. Slide (Arrangement of granite and gabbro with associated minerals)

1. Dull, tedious; thought of other things	____ ____ ____ ____ ____	Interesting; held my attention
2. Repeated what I already knew	____ ____ ____ ____ ____	Informative; presented new material
3. Too easy to follow; too elementary	____ ____ ____ ____ ____	Too difficult to follow; too advanced
4. I did not like this way of presenting material	____ ____ ____ ____ ____	I liked this way of presenting material
5. Did not fit in well with other lab activities	____ ____ ____ ____ ____	Fit in well with other lab activities

ITEM III. Earth materials - use of whole and crushed granite and gabbro and use of associated common minerals

1. Dull, tedious; thought of other things	____ ____ ____ ____ ____	Interesting; held my attention
2. Repeated what I already knew	____ ____ ____ ____ ____	Informative; presented new material
3. Too easy to follow; too elementary	____ ____ ____ ____ ____	Too difficult to follow; too advanced
4. I did not like this way of presenting material	____ ____ ____ ____ ____	I liked this way of presenting material
5. Did not fit in well with other lab activities	____ ____ ____ ____ ____	Fit in well with other lab activities

FORM C (Continued)

ITEM IV. Earth Models - Hardness

1. Dull, tedious; thought of other things	___	___	___	___	___	Interesting; held my attention
2. Repeated what I already knew	___	___	___	___	___	Informative; presented new material
3. Too easy to follow; too elementary	___	___	___	___	___	Too difficult to follow; too advanced
4. I did not like this way of presenting material	___	___	___	___	___	I liked this way of presenting material
5. Did not fit in well with other lab activities	___	___	___	___	___	Fit in well with other lab activities

ITEM V. Laboratory Assistance

1. This unit provided no reinforcement by giving answers	___	___	___	___	___	This unit provided all of the answers, as needed
2. Lab assistants remain aloof; indifferent to my questions	___	___	___	___	___	Lab assistants are sympathetic; eager to help
3. Lab assistants are never available to answer questions	___	___	___	___	___	Lab assistants are always available to answer questions
4. I did not seek or receive assistance during this unit	___	___	___	___	___	I sought and received assistance several times during this unit

ITEM VI. Lab Manual - Rate the manual as a guide to the unit as a whole

1. Dull, tedious; thought of other things	___	___	___	___	___	Interesting; held my attention
2. Repeated what I already knew	___	___	___	___	___	Informative; presented new material
3. Too easy to follow; too elementary	___	___	___	___	___	Too difficult to follow; too advanced
4. I did not like the way the manual presented the material	___	___	___	___	___	I liked the way the manual presented the material

FORM D

ATTITUDE QUESTIONNAIRE

1. I am very excited about the AVT laboratory program.
2. If I had my way, I'd compel everyone to take the AVT program.
3. The AVT laboratory program is of great value.
4. I really enjoyed the AVT laboratory.
5. The AVT laboratory sessions fascinate me.
6. The merits of this lab program far outweigh the defects.
7. Anyone who takes the AVT lab program is bound to benefit.
8. The AVT lab program is a good program.
9. The AVT lab program teaches methodical reasoning.
10. This lab program serves the needs of a large number of students.
11. All lessons and all methods used in the AVT lab are clear and definite.
12. The AVT lab program has its merits and fills its purpose quite well.
13. The AVT lab is not receiving its due recognition in colleges and universities.
14. This laboratory program is not a bore.
15. This laboratory program has its drawbacks, but I like it.
16. The AVT lab program might be worthwhile it it were presented right.
17. My likes and dislikes for this program balance one another.
18. The AVT laboratory program will benefit only the brighter students.
19. I could do very well without the AVT lab program.
20. The minds of students are not kept active in the AVT laboratory.
21. I am not interested in the AVT lab program.
22. This lab program does not teach you how to think.
23. The AVT lab program is dull.
24. The AVT lab program does not hold my interest at all.
25. I have no desire for this lab program.
26. I have seen no value for this lab program.
27. I would not advise anyone to take this lab program.
28. The AVT lab program can't benefit me.
29. This lab program is a waste of time.
30. Nobody likes the AVT lab program.
31. I detest the AVT laboratory.
32. Words cannot express my antagonism towards the AVT lab program.
33. I hate the AVT laboratory program.

Part I. DIRECTIONS: Answer each question by selecting the BEST response from those given. Mark the appropriate slot on the official scoring sheet using a Number 2 pencil. Mark only one correct answer per question; if you change your mind, erase any other mark completely. Read carefully; a question may have several partially correct answers, but only one BEST answer.

1. How many GENERA are represented in the following list?

   Panthera leo
   Felis pardalis
   Panthera onca
   Lynx rufus

   a. One
   b. Two
   c. Three
   d. Four

2. In the Colorado Plateaus region, rocks found on a mesa overlooking a nearby river valley can be said to be younger than those found in the valley bottom. The basis for this statement is the concept of:
   a. Uniformity of Process.
   b. Superposition.
   c. Fossil Correlation.
   d. Isostatic Adjustment.

3. Deposition of sediments in a stream increases as
   a. stream velocity decreases.
   b. stream velocity increases.
   c. particle size decreases.
   d. volume of water increases.

4. On a hypothetical planet having a circumference of 44,000 miles, our latitude-longitude system superimposed on the planet would result in which of the following?
   a. Each degree of latitude and longitude equals approximately 120 miles.
   b. Each degree of longitude at the equator equals approximately 80 miles.
   c. Each degree of longitude equals approximately 120 miles.
   d. Each degree of longitude at the equator equals approximately 120 miles.

5. An analysis of minerals present in gabbro would be closest to
   a. 30% quartz, 20% biotite and 50% feldspar.
   b. 5% feldspar and 95% augite.
   c. 40% feldspar, 30% augite and 20% biotite.
   d. 80% feldspar and 20% augite.

6. Rock salt deposits in the earth were formed
   a. by the evaporation of sea water.
   b. by neutralization of NaOH in the rocks with HCL.
   c. as molten halite cooled.
   d. from calcite.

7. The tops of major ridges in western Pennsylvania are usually supported by
   a. limestone.
   b. shale.
   c. siltstone.
   d. sandstone.

8. Rejuvenation, a process associated with the Colorado Plateau region, is best illustrated by:
   a. volcanics in the Ship Rock area.
   b. streams along the San Juan River region.
   c. indian cliff houses at Spruce Tree House.
   d. deposits of sediments in Lake Mead.

9. On a certain river in the Rocky Mountains one sees a V-shaped valley downstream; however, the upstream portion of this sam valley is U-shaped. This change in valle shape is most likely due to:
   a. differential erosion of dissimilar rock types.
   b. glacial erosion upstream; stream erosion downstream.
   c. glacial erosion throughout the entire valley.
   d. stream erosion upstream; glacial erosion downstream.

10. When comparing surface features in the Ridge and Valley Province and the Allegheny Plateau, major differences can be seen in
    a. stream patterns.
    b. highway trends.
    c. mountain or ridge shapes.
    d. all of the above.

11. Two rock specimen from different parts of the world are known to contain quartz, mica and feldspar. In order to classify them properly, the next step is to determine the
    a. density and specific gravity of each rock.
    b. proportions of each mineral present.
    c. cleavage angles of the minerals in each rock.
    d. hardness of each rock specimen.

Study of sedimentary structures such as those listed below in questions 12 and 13 yields information as to the environment during rock formation. This information may be:

I. Direction of current
II. Top and bottom of beds
III. Nature of site- deep ocean, mud flat, sand bar, etc.

With regard to each structure listed in 12 and 13,

If it yields information on I and II <u>only</u>, select A on your answer sheet.
If it yields information on II and III <u>only</u>, select B on your answer sheet.
If it yields information on I and III <u>only</u>, select C on your answer sheet.
If it yields information on <u>I, II and III</u>, select D on your answer sheet.

12. Mudcracks

13. Cross-bedding

Questions 14-16 concern the following <u>observations</u> of a rock:

1. The rock is light colored.
2. It is composed of large crystals which are easily visible to the unaided eye.
3. It contains appreciable amounts of quartz and feldspar.

Check each of the statements below (14-16) to see if it is contradictory to the observations given above.

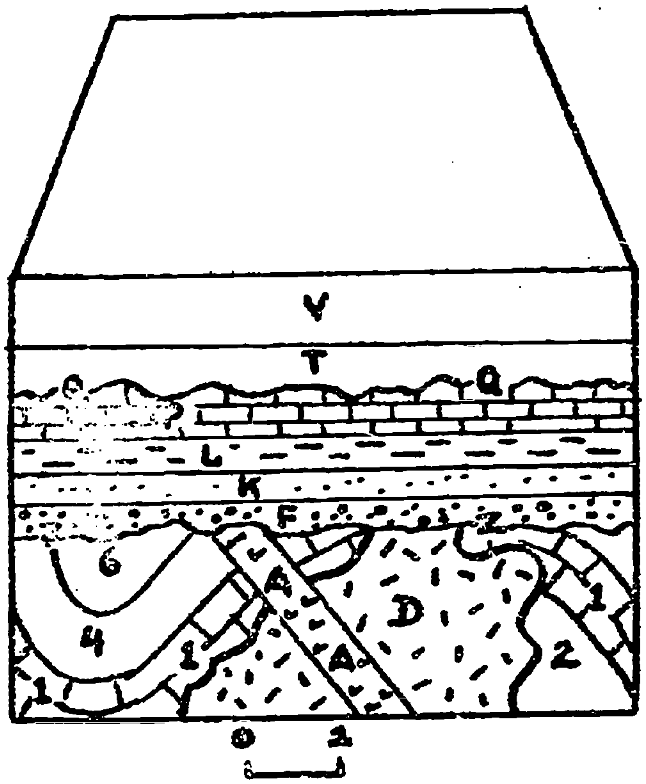
If observation 1 contradicts the statement, darken A on the answer sheet.
If observation 2 contradicts the statement, darken B " " " "
If observation 3 contradicts the statement, darken C " " " "
If NONE of the observations contradict the statement, darken D on the answer sheet.

14. The rock may have a granular fabric.

15. The rock may be felsite.

16. The rock may have formed near the surface.

Diagram I



17. In diagram I, surface "Z" is most nearly like the surface
    a. at Q.
    b. between "F" and "K".
    c. between 1 and 4.
    d. between "D" and 2.

18. In diagram I, which of the geologic events listed below is oldest?
    a. Intrusion of "A"
    b. Intrusion of "D"
    c. Folding of 1, 2, 4 and 6
    d. Erosion of surface "Z"

19. Standing on a high ridge in western Pennsylvania, you are aware that this north-south trending ridge is actually the west flank of a syncline. To find older rocks, you would then walk
    a. northward.
    b. southward.
    c. eastward.
    d. westward.

20. Which of the following processes has been chiefly repponsible for the presence of marine sediments a mile above sea level in Colorado?
    a. Isostatic adjustment
    b. Folding
    c. Intrusion
    d. Volcanic activity

21. Rocks weather because they are
    a. exposed to carbon dioxide (CO_2).
    b. not stable in the presence of water.
    c. oxidized by oxygen dissolved in water.
    d. not at equilibrium with the environment.

22. The best way to distinguish quartzite from sandstone is
    a. to apply dilute HCL to oach.
    b. in observing and measuring cleavage faces.
    c. by observing the surface of fracture with a lens.
    d. by recording color differences between the two.

23. When comparing two 30-minute topographic maps from different parts of the United States (Alaska VS. Ohio), it may be said that
    a. both maps represent the same number of square miles.
    b. the Alaskan map contains a smaller number of square miles.
    c. the Ohio map contains a smaller number of square miles.
    d. the fact that they are called 30-minute sheets has nothing to do with areas involved.

24. All samples of granitic gneiss and marble are alike in that they are
    a. of the same composition.
    b. foliated.
    c. derived from similar parent rocks.
    d. metamorphic.

25. The fact that sedimentary rocks now found at "mile-high" Colorado were once sea level sediments is best supported by examination of outcrops of:
    a. Fountain sandstone.
    b. Niobrara limestone.
    c. Silver Plume granite.
    d. lava flows at Table Mesa.

26. Given the following locations.....

    Place 1 at lat. 20° N., long. 50° E.
    Place 2 at lat. 30° N., long. 50° E.
    Place 3 at lat. 30° N., long. 60° E.
    Place 4 at lat. 20° N., long. 60° E.

    ....which of the places listed below are farthest from each other?

    a. Place 1 and place 4
    b. Place 2 and place 3
    c. Place 2 and place 4
    d. All places are the same distance from each other.

27. On what basis do scientists conclude that fossil corals required a warm, shallow-water environment?
    a. The composition of rocks in which fossil corals are found.
    b. The geographic distribution of fossil corals.
    c. Most present-day corals live in this type environment.
    d. Corals are composed of calcium carbonate.

28. A unit of rock distinguished by its fossil content is a
    a. zone.
    b. layer.
    c. facies.
    d. formation.

29. According to Mohs' Scale of hardness
    a. absolute values are not assigned to minerals.
    b. diamonds are about nine times harder than talc.
    c. minerals not having cleavage appear as higher values.
    d. the force applied to each mineral type must be equal.

30. The table below describes the ranges of 3 fossils found in a layer of sedimentary rock:

SPECIES	FROM	UP TO AND INCLUDING
Fossil A	Early Cambrian	Early Ordovician
Fossil B	Late Cambrian	Late Ordovician
Fossil C	Middle Cambrian	Late Cambrian

    The age of this fossil assemblage is closest to:
    a. Late Cambrian.
    b. Early Ordovician.
    c. Late Cambrian through Early Ordovician.
    d. Early Cambrian through Late Ordovician.